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PERMANENT MARK RECORDER FOR LASER WEAPON FIRE SIMULATORS,(U)
APR 78 R W MACPHERSON, C ETHIER, M GRAVEL
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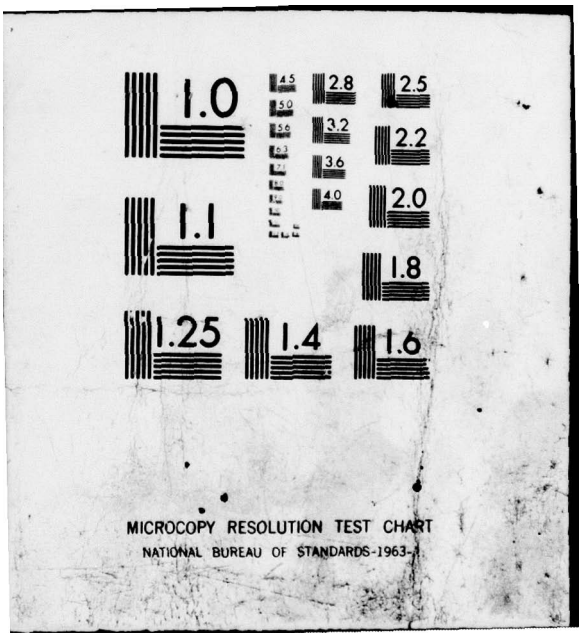
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CRDV RAPPORT 4101/78
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PERMANENT MARK RECORDER FOR LASER WEAPON FIRE SIMULATORS

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Valcartier, Québec

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MINISTÈRE DE LA DÉFENSE NATIONALE
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(6) PERMANENT MARK RECORDER FOR LASER WEAPON FIRE SIMULATORS,

by

(10) R.W. MacPherson, C. Ethier and M. Gravel

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RESUME

Ce rapport décrit un appareil développé au CRDV pour enregistrer sur film Polaroid le tir des lasers simulateurs d'armes. Cet appareil élimine l'usage de la carabine .22 dans des exercices d'entraînement sur les chars de combat, tel celui de la constance de visée. Ce document donne le principe de fonctionnement et la description des composants d'un modèle expérimental qui pourra servir de base à une version industrielle en vue d'essais intensifs. Il pourra également servir de manuel de fonctionnement et d'entretien pour le modèle expérimental. (NC)

ABSTRACT

This report describes the Mark Recorder developed at DREV to record laser weapon fire simulator hits on Polaroid film. This device eliminates the need for .22 calibre practice ranges for tank gunnery training exercises such as consistency-of-lay tests. The document gives the principles of operation and construction details of a development model which will enable industry to develop engineering models suitable for extensive user testing and evaluation. It is also intended as an operation and maintenance manual for the development model. (U)

TABLE OF CONTENTS

1.0 INTRODUCTION

Since October 1968, Combat Arms School (CAS) has been using a laser weapon fire simulator for tank gunnery training. In 1970, CAS recommended its use by the Canadian Forces (Ref. 1). In 1973, DREV developed an improved version (Ref. 2) and subsequently the Land Engineering Test Establishment (LETE) manufactured 14 units. Although the laser weapon fire simulator was intended to replace the small-calibre weapon used in training and thus to reduce the safety requirements for the miniature ranges, consistency-of-lay and zeroing exercises still require the use of a .22 calibre weapon since the laser weapon fire simulator leaves no permanent record of hits.

The aim of the present task is to develop a method for providing a long-duration or permanent record of the laser weapon fire simulator hits in the Tank Miniature Range, and thus eliminate the need for a separate .22 calibre range. At present, expensive electro-optics systems which record the beam position on a television image tube and display it on a monitor (Ref. 3) are available, but there seems to be no suitable device to perform the task at low cost. Simpler systems such as the 'electric eye' shooting gallery found, for example, in amusement parks are not adequate since they only indicate hits on point or near point targets and they have no means of measuring miss distances, zeroing errors or the hit distribution.

An ordinary camera synchronized with the laser weapon fire simulator would, in principle, be capable of making such recordings, but it has no independent means of adjusting the relative intensities of the laser light and the target illumination for proper exposure. Furthermore, such a system would be sensitive to ambient lighting conditions and would require time-consuming positioning, focusing and exposure adjustments every time it is used in a new place or under unfamiliar lighting conditions. Television monitors suffer from the same limitations and, also, are considerably more expensive. In addition, the use of more powerful lasers capable of marking the target directly is not acceptable from the point of view of safety, cost and reliability.

The Mark Recorder described here incorporates a target screen and uses conventional Polaroid[R] films. The device is activated by a signal from the existing laser weapon fire simulator and records the complete series of shots necessary to perform up to six consistency-of-lay tests on a single photograph. Throughout the test sequence, the trainee sees no permanent mark of his earlier shots and is, therefore, less inclined to attempt to compensate for previous errors.

[R] Registered trademark of the Polaroid Corporation.

This work was performed at DREV between September 1976 and June 1977 for the Director Land Armament and Electronics Engineering and Maintenance (DLAEEM) under PCN 21T34 (formerly 34D40), Permanent marker for laser weapon fire simulator used in the tank miniature range.

2.0 REQUIREMENTS

The basic requirements for a laser mark recording device were established through consultation with DLAEEM officers and potential users at CFB Valcartier and CFB Gagetown. These requirements can be summarized as follows:

a) the device should provide a long-duration or permanent record of laser hits, since several seconds are required to read the coordinates of hit positions;

b) it should be compatible with the HeNe laser weapon fire simulator currently used for training on the Tank Miniature Ranges; only minor modifications are acceptable;

c) the device should be portable, easy to use, safe, require little servicing and cost little to operate;

d) electrical power, if needed, should be provided by the 24 V DC source available on the tanks;

e) the device should show an array of six 5-cm square targets exhibiting only cross hairs on a highly contrasting background;

f) the user, when shooting, should not see the marks left by his previous shots in order to avoid being influenced by previous errors or misalignment of the gun optics;

g) the device should be able to operate under different ambient lighting conditions;

h) the precision provided should be at least as good as that provided by the .22 calibre rifle.

3.0 DESCRIPTION

3.1 Mark Recorder Unit

The basic componant of the Mark Recorder unit developed to satisfy the above requirements is a camera permanently focused on the rear of a translucent target screen. The device photographs the screen at the instant the laser weapon fire simulator is fired.

As illustrated in Fig. 1, the unit comprises a target screen, a reversing mirror, a lens, an electronic shutter and a film holder, together with shutter control electronics, and an illuminated graticule which are all contained in a single housing approximately 45 cm long, 20 cm high and 18 cm deep. All controls are grouped together on a single panel. The unit uses 2 A at 24 V DC supplied by the tank and weighs 11 kg. A list of the mechanical drawings and of the electrical and optical components appears in Appendices A and B respectively.

3.2 Operation

Figure 2 shows the principle of operation. The tank gunner shoots at a point on the target screen with the laser weapon fire simulator. The laser beam passes through the screen and is focused with the illuminated graticule onto the film by the 105 mm f/4.5 lens. The magnification is approximately 0.625. The shutter, which is located behind the lens, opens on a signal from the simulator and closes after the correct exposure time has elapsed. Once the required number of shots has been fired, the Polaroid[R] film is processed in the conventional manner. The resulting photograph, which displays a permanent record of the laser hits along with a grid pattern, can be used to make a quantitative assessment of the gunner's performance.

3.3 Target Screen

The key element in the Mark Recorder is the target screen detailed in Fig. 2. It performs several functions:

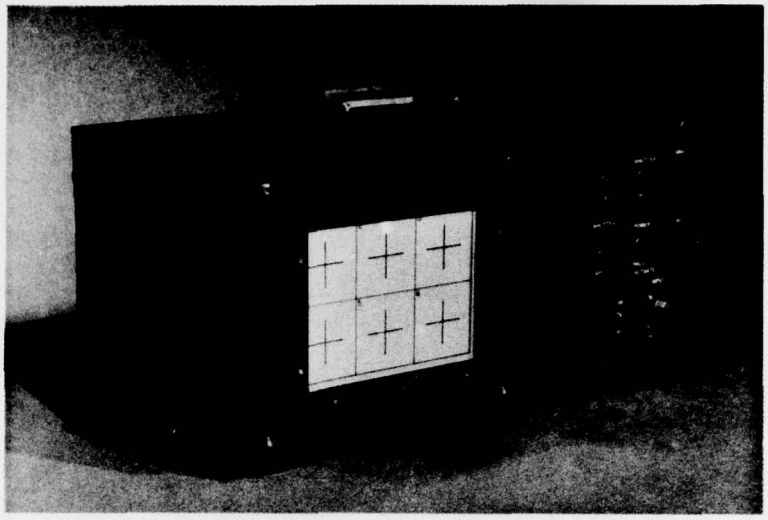
a. presents a target to the gunner,
b. blocks ambient light from overexposing the film but transmits the laser light,
c. provides a diffusing surface for the laser hits,
d. provides an illuminated grid which is photographed but is unseen by the gunner.

The target screen consists of several layers of material: an outside protective window of non-glare glass such as is used in picture frames, a sheet of high-quality white paper with the target printed on it, six layers of Rubylith[R] masking film acting as a filter against ambient light, and a 4.8 mm thick clear acrylic sheet on which a graticule is engraved. The Rubylith[R] was used as a matter of convenience since it is thin and relatively inexpensive. As shown in Fig. 3, it blocks most light with a wavelength shorter than 600 nm and has transmission characteristics similar to those of the Schott glass filter No. OG590. A series of eight No. 382 miniature incandescent lamps mounted on the perimeter of the acrylic sheet illuminates the graticule. An aluminum frame holds the entire target screen on the side of the housing.

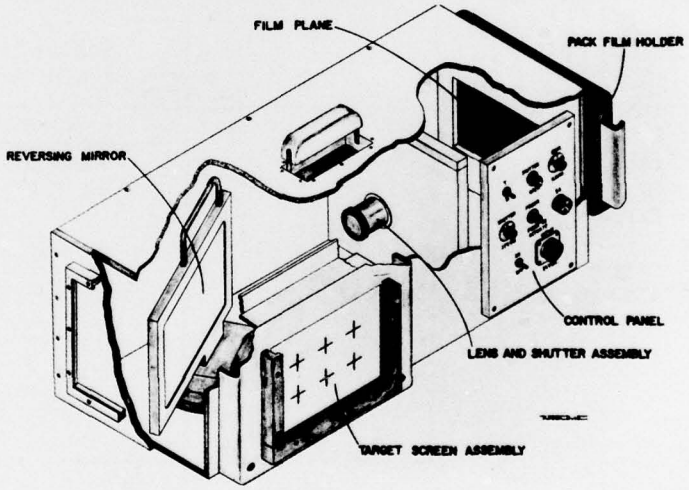
[R] Registered trademark of Ulano companies.

3.4 Electrical Circuit

A complete schematic diagram of the electrical circuit appears in Fig. 4. The 24 V DC supply charges a large pulse capacitor through a 1 kΩ resistor, powers the illuminating lamps and also drives a 12 V, 1 A voltage regulator which supplies power to the remainder of the circuit. A rheostat, mounted on the control panel, controls the graticule lamp current to provide adjustable illumination. A pulse from the laser weapon fire simulator triggers a 555 timer circuit which provides a variable 4 ms to 0.1 s pulse to the base of a power Darlington transistor which, in turn, discharges the pulse capacitor through the shutter to open it. A 250 mA holding current, provided by a diode and a 15 Ω resistor in series with the 12 V supply, keeps the shutter open until the power Darlington transistor is turned OFF. A full-size illustration of the circuit board foil pattern appears in Fig. 5 and an illustration of the parts layout, in Fig. 6.

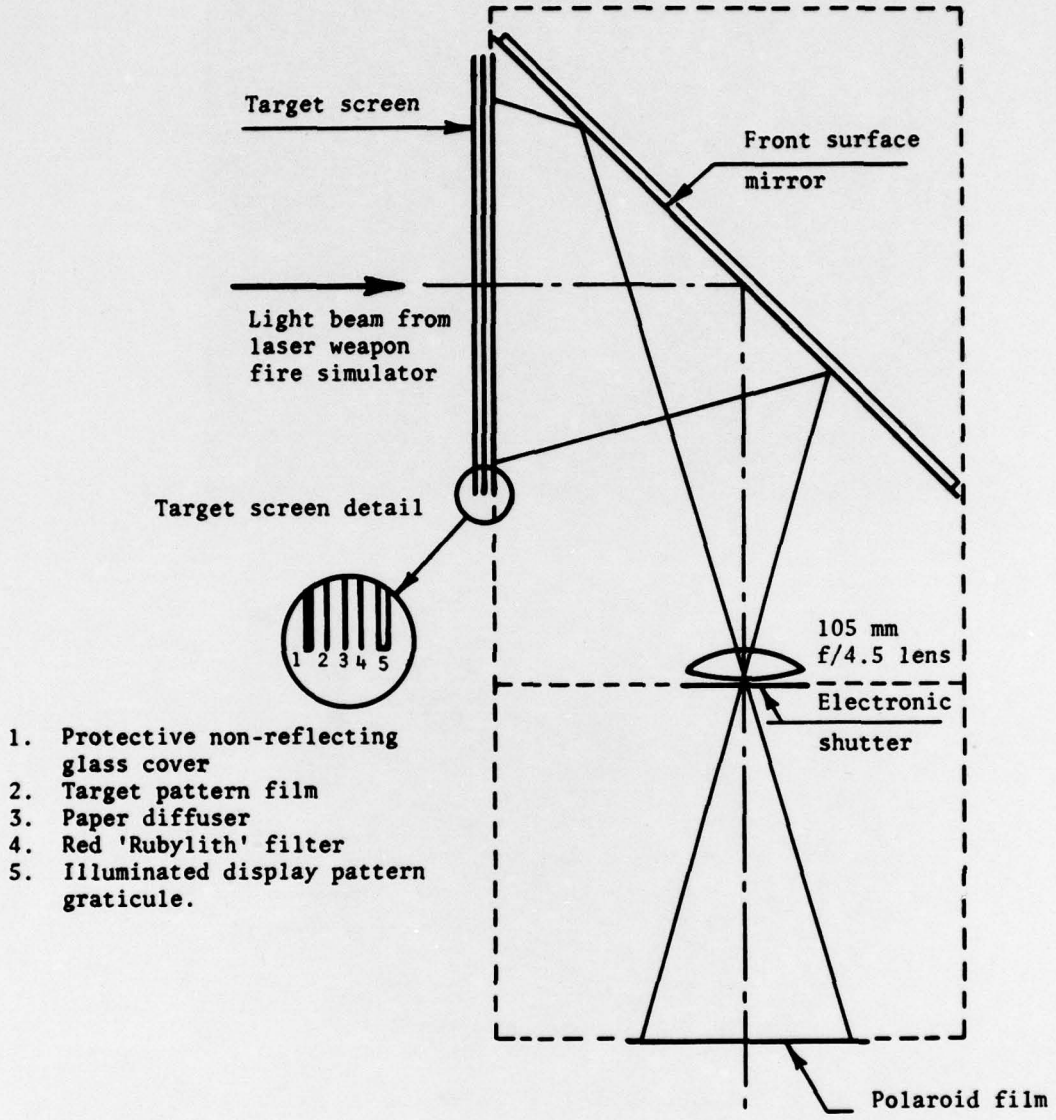


(a)



(b)

FIGURE 1 - Photograph (a) of the development model of the Mark Recorder and a cut-away drawing (b) showing the placement of the various components. The six cross hair targets appear on the front of the target screen as they would be seen by the gunner. The rear of the screen has an illuminated graticule which is photographed along with the laser hits by means of the lens and shutter assembly and the film in the pack film holder. The reversing mirror reverses the rear view image to obtain the correct orientation. The control panel contains all the necessary adjustments for shutter speed and graticule illumination, power connection, ON-OFF switch as well as certain test functions. The bracket on the left end stores the covers for the target screen and control panel and the ground glass alignment screen when they are not in use.



1. Protective non-reflecting glass cover
2. Target pattern film
3. Paper diffuser
4. Red 'Rubylith' filter
5. Illuminated display pattern graticule.

FIGURE 2 - Schematic diagram of the Mark Recorder as viewed from above showing the light path. Light from the laser weapon fire simulator strikes target and diffuser in the target screen. The scattered laser beam and the illumination from the graticule are reflected by the mirror and then focused onto the film by the camera lens. The Rubylith^{R} filter in the target screen blocks out most of the ambient light. The lens opening and electronic shutter control the film exposure. The mirror serves to reorient the image of the target which is reversed because it is photographed from the rear.

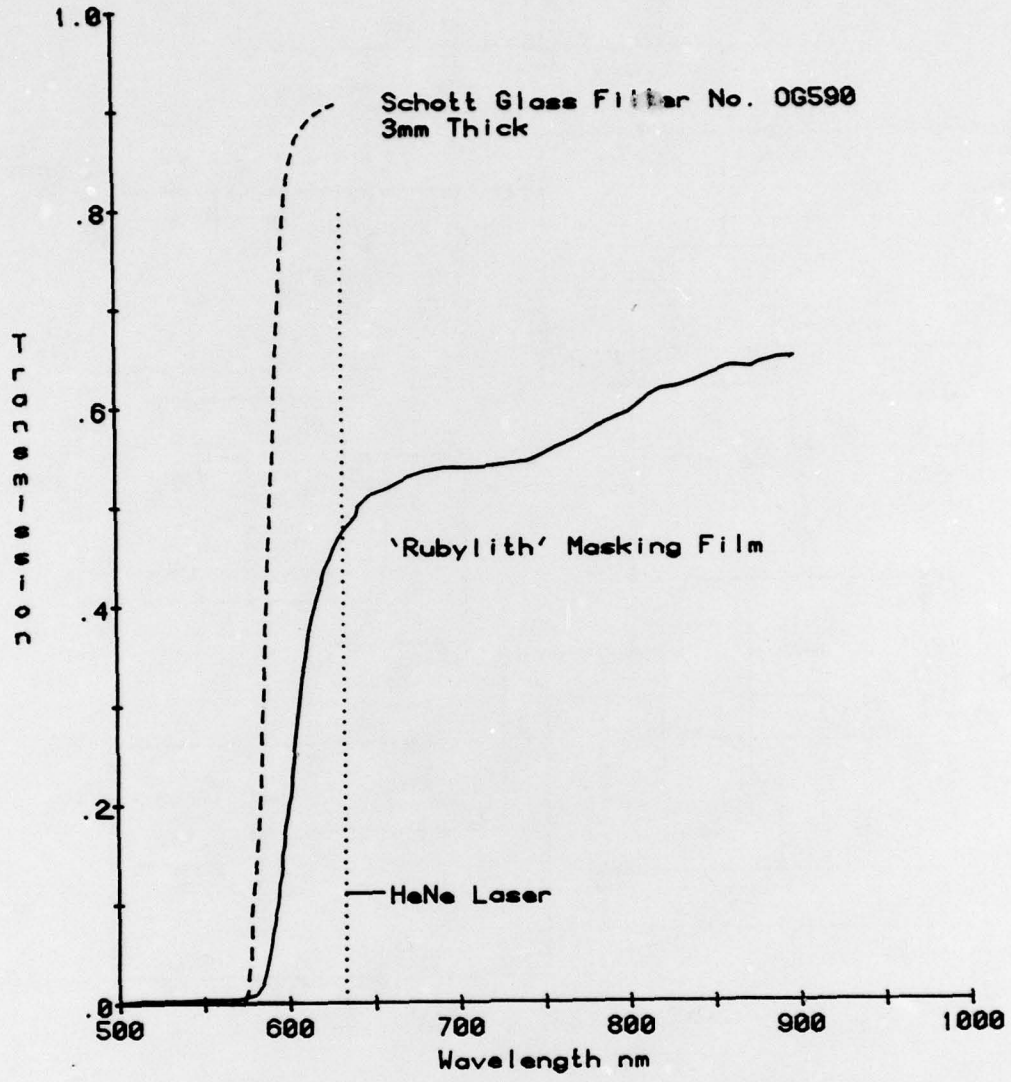


FIGURE 3 - Transmission curves of a single layer of Rubylith[R] masking film and a 3 mm thick Schott glass filter No OG590. Both effectively block most of the light below 600 nm. However, the overall transmission of the masking film is considerably less than that of the glass filter. The HeNe laser is so intense that it easily penetrates the six layers of Rubylith[R] used in the target screen while the transmission of ambient light above 600 nm is reduced to less than 6%. The dotted line represents the operating wavelength of the HeNe laser at 632.8 nm.

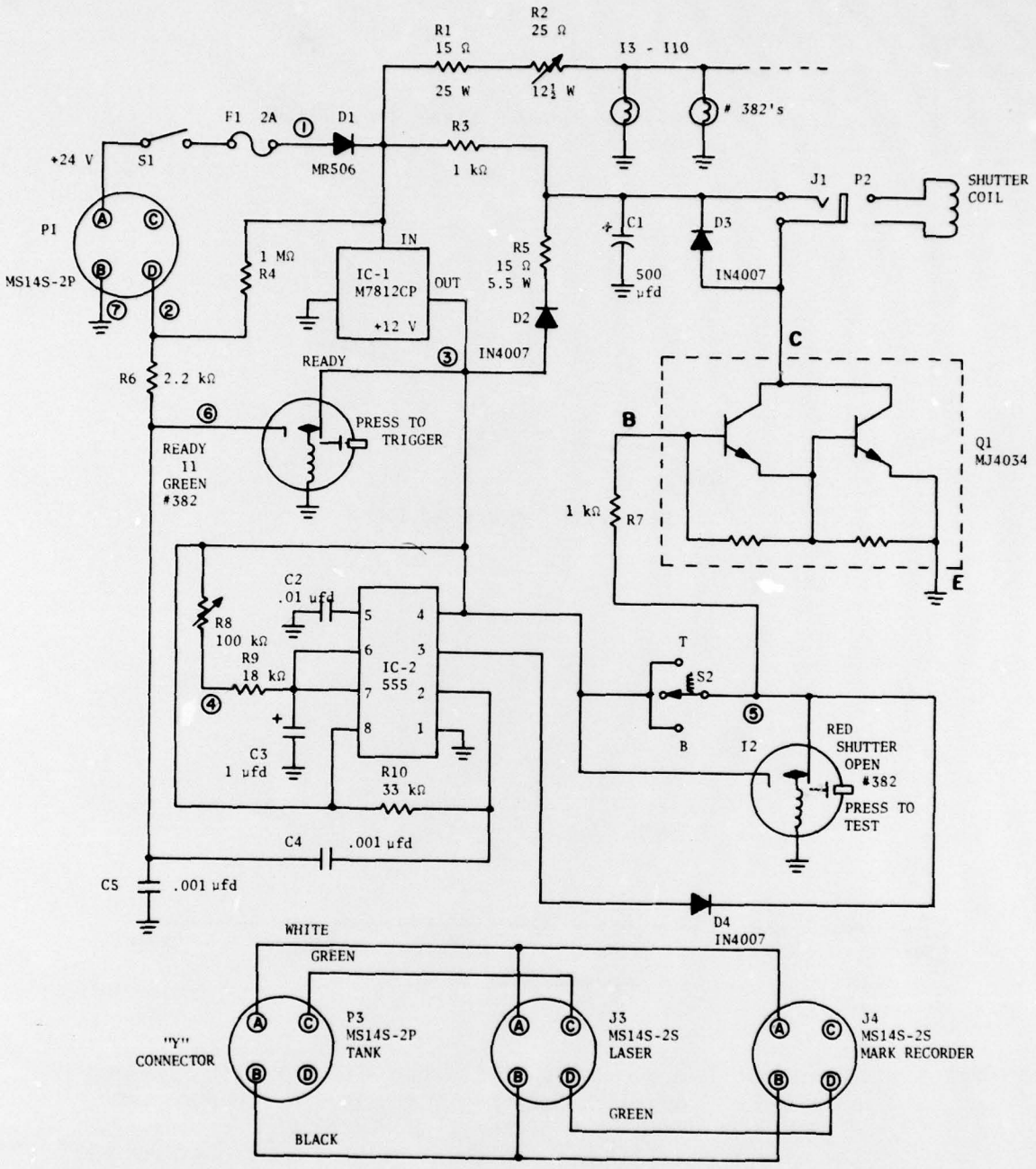


FIGURE 4 - Electrical circuit. Encircled numbers indicate terminal points on the circuit board.

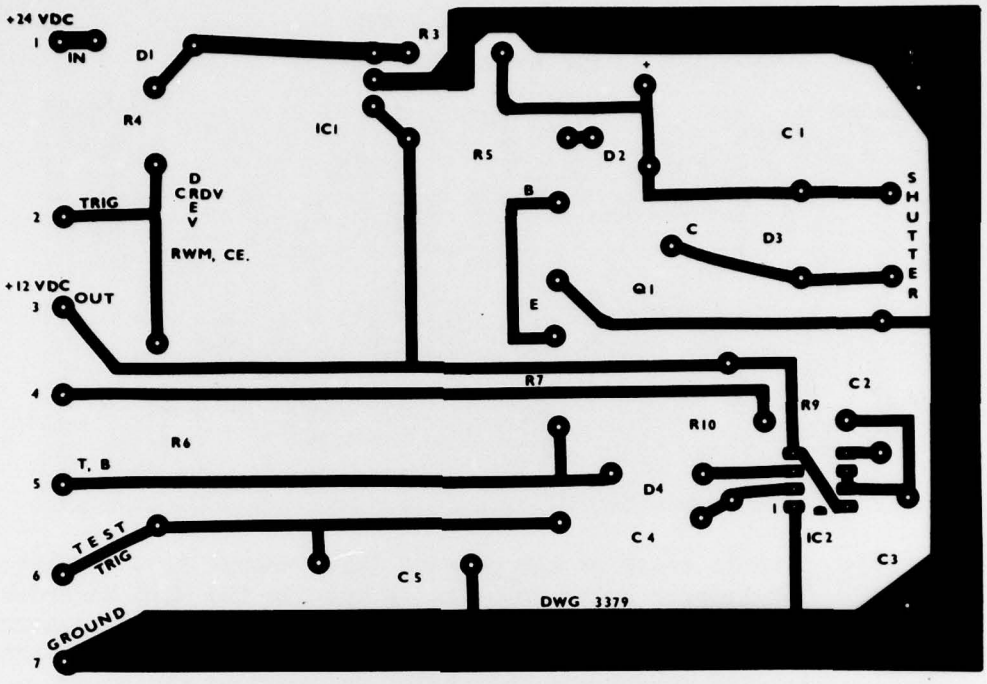


FIGURE 5 - Circuit board foil pattern. Scale is full size.

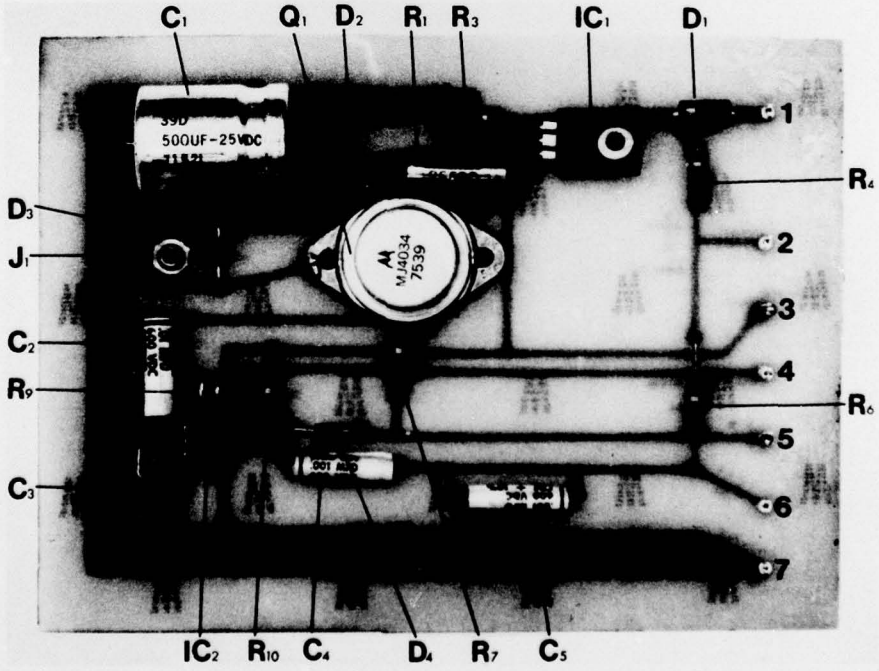


FIGURE 6 - Circuit board parts layout. Part numbers refer to components in the electrical circuit, Fig. 4.

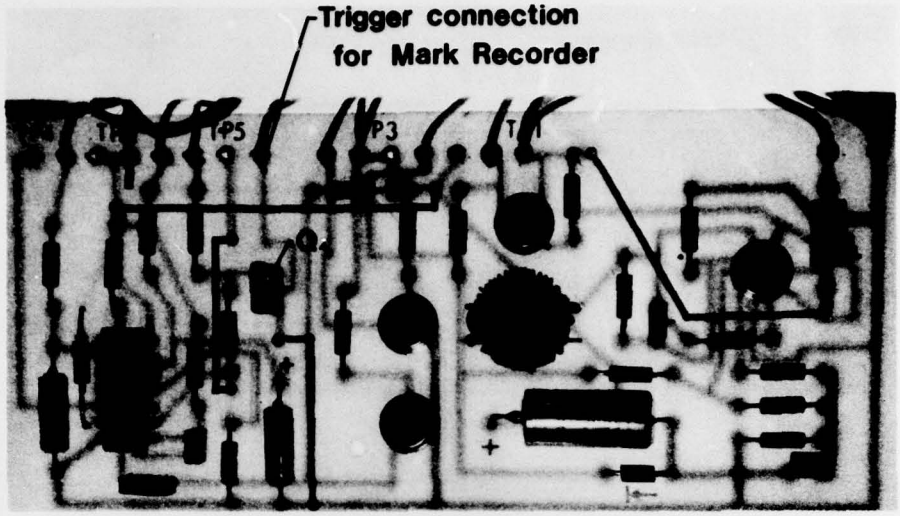


FIGURE 7 - Circuit board of the present laser weapon fire simulator. The trigger pulse required to operate the Mark Recorder is obtained from the collector of Q4 at the pin adjacent to TP5 as shown. A ~20-cm long, 22-gauge flexible wire is used to connect this point to pin D on the power connector of the simulator.

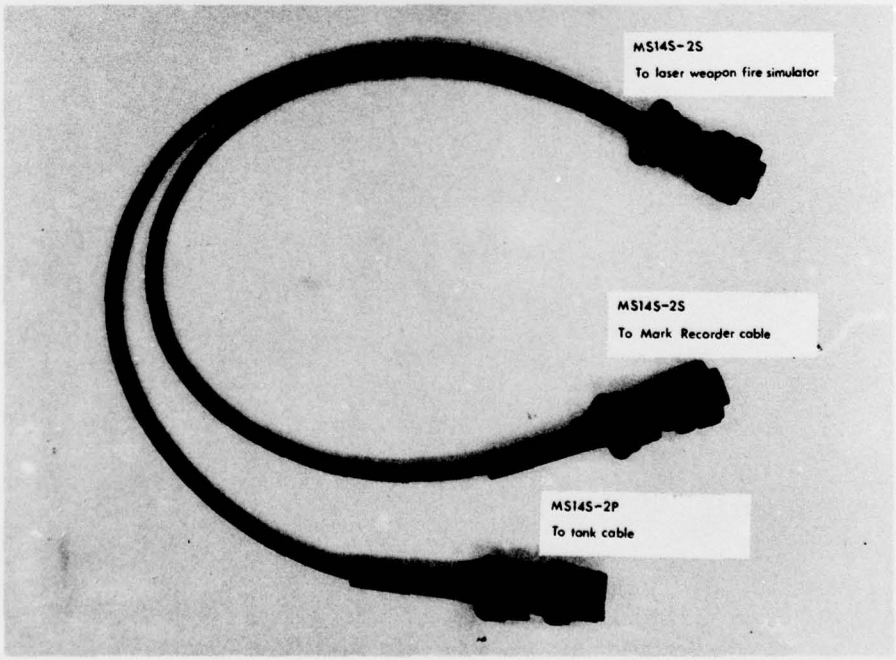


FIGURE 8 - "Y" connector cable. The connections to each end of the cable are indicated in the photograph. The wiring schematic is included in Fig. 4.

4.0 INSTALLATION INSTRUCTIONS

Certain minor modifications must be made to the existing laser weapon fire simulator before the Mark Recorder can be used for the first time, but they will not affect the current operation of the simulator.

To function, the Mark Recorder camera requires a trigger pulse from the weapon fire simulator. It is obtained from the solenoid switching transistor, Q4, located on the circuit board in the simulator, by connecting a 22 gauge, flexible, insulated wire approximately 20 cm long from pin D of the power plug to the collector of Q4 at the standoff connecting post adjacent to TP5 (see Fig. 7 of this report and Ref. 4 for details).

The telescope supplied with the laser weapon fire simulator is of the fixed focus type and collimates the laser into a ~1-cm diameter beam. Since this beam is too wide to provide the accuracy of position required by the Mark Recorder,the telescope has to be refocused at 16 m (53'), the normal operating distance for such exercises as consistency-of-lay practice. This is accomplished by unscrewing the output lens a few turns to obtain the minimum spot size at 16 m. The lens is fixed in place by a locking ring which should be loosened first. Note that both the locking and the lens rings are held with glue which can be softened sufficiently by gently heating the end of the telescope with a heat gun. The focused spot will be approximately 3 mm in diameter and will provide greater precision for consistency-of-lay exercises than is currently available with the .22 calibre rifle. The laser beam will then diverge beyond the focal point but its diameter will still be smaller over the entire range of interest (up to ~30 m in the Tank Miniature Ranges) than it was for the collimated beam.

Finally, to provide power and the trigger signal to the Mark Recorder, the special "Y" cable shown in Fig. 8 should be connected between the cable from the tank supply and the laser weapon fire simulator. The third connector goes to the Mark Recorder cable. A schematic diagram of the cable wiring is included in Fig. 4.

5.0 OPERATING INSTRUCTIONS

5.1 Safety Precautions

The control circuits operate at a relatively safe 24 V DC. All exposed terminals are contained within the case and should present no hazard or difficulty under normal use. However, if the unit is operated with any of its panels removed, care must be exercised to avoid damage to any of its components.

The Polaroid^{R} film packs used in the camera contain corrosive substances which may be injurious to the eyes or skin on contact. Therefore, it is recommended that the safety directions that accompany the Polaroid^{R} film be carefully followed to ensure that no problems are encountered.

5.2 Camera Alignment

Under normal operating conditions and after the initial Mark Recorder alignment, the camera should require no further adjustment. However, if the alignment is unsatisfactory the following procedures should be performed. For both centering and focusing procedures, first replace the film pack with the ground glass plate supplied with the Mark Recorder. Turn the power switch ON and open the shutter by switching the T, B switch on the front panel to T. Turn the graticule illumination control fully clockwise and open the lens aperture to its maximum to view the image of the graticule on the ground glass. The room lights may require dimming to see the image distinctly.

5.2.1 Centering

The optical axis of the lens is fixed with respect to the target screen. The only adjustment available is the orientation of the reversing mirror which has two degrees of freedom: a $\pm$ 2.5° rotation about the vertical and the horizontal axes.

To center the image of the target screen horizontally on the ground glass, loosen the two saddle retaining screws on the mirror mount as shown in Fig. 9, and rotate the mirror assembly about the vertical axis until alignment is achieved. Tighten the retaining screws.

To center the image vertically, loosen the two socket head screws which lock the rocking base of the mirror mount and then tighten one or the other to obtain the correct positioning. Tighten the second screw to lock the mirror frame in place. Do not use excessive force and keep in mind that, since these two screws work in opposition to each other, one cannot be tightened without first loosening the other.

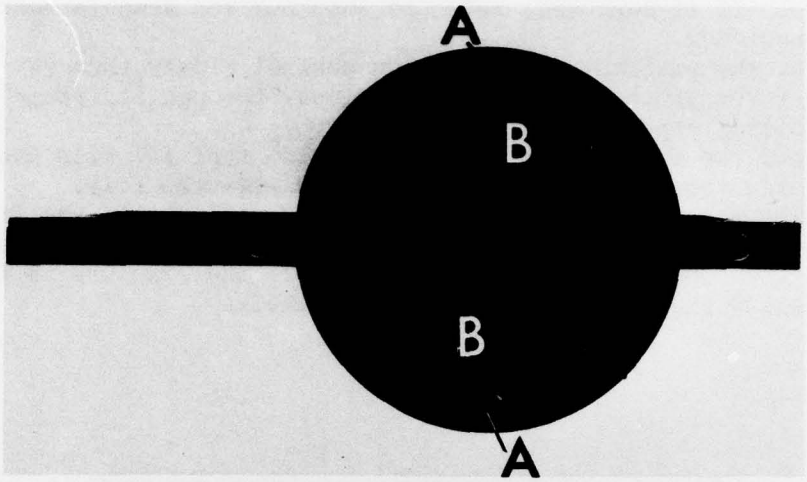


FIGURE 9 - View of the mirror mount from above. The large screws, A, are loosened to permit rotation of the mirror about the vertical axis. The smaller screws, B, are used to adjust rotation about the horizontal axis. See text for details.

5.2.2 Focusing adjustment

To focus the camera, loosen the two retaining bolts in the support of the lens board assembly and slide the entire assembly along the optic axis to obtain the best focus. Lock the board in position by tightening the retaining bolts. Open the lens to its widest aperture (f/4.5) for the most precise focusing.

Note that if the camera is badly misaligned some interaction will occur between both centering and focusing operations. This will generally appear as an inability to focus both sides or the top and bottom of the image simultaneously. Repeat the two procedures as often as necessary to obtain satisfactory alignment. Replace the film holder after alignment is completed.

5.3 Operating Adjustment Procedure

1. Ensure that the laser weapon fire simulator has been modified for use with the Mark Recorder as described in Sec. 4.
2. Make sure that the power switch is OFF and connect the power-trigger cable between the special "Y" cable at the simulator and the Mark Recorder.

3. Turn the power switch ON. The ready light (green) should go on. If it does not, refer to Sec. 6.2 for troubleshooting procedure.
4. Set the graticule illumination control midway through its range.
5. Set the shutter speed control midway through its range for the initial exposure.
6. Load the film holder with a Polaroid^{R} type 107 film pack following the instructions supplied with the film.
7. Fire the required number of "rounds" and develop the film according to the instructions supplied with the film pack. Figure 10 shows a typical record. If the exposure is not acceptable, follow the directions given in Sec. 6.2.

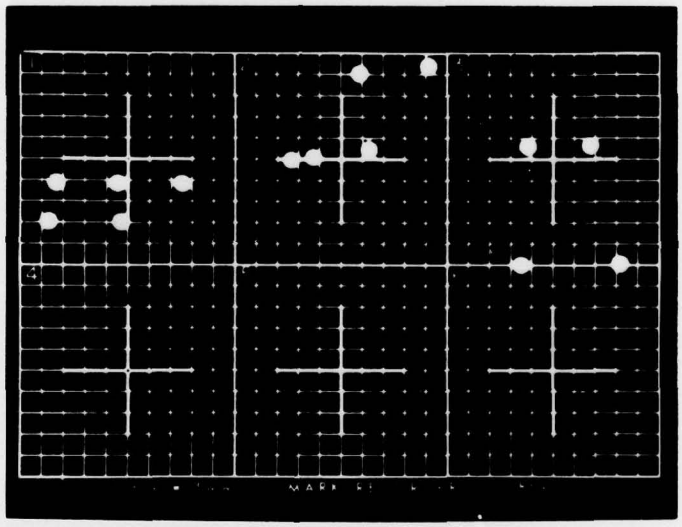


FIGURE 10- Record of laser weapon fire simulator hits obtained from the Mark Recorder. Miss distances can easily be determined from such a record to provide a quantitative measure of the gunners' performance.

6.0 MAINTENANCE AND SERVICING

6.1 General Maintenance

Under normal use, only the Polaroid[R] film holder will require regular maintenance. Follow the manufacturer's instructions, particularly those related to cleaning the rollers. These should be cleaned daily after use and especially before the Mark Recorder is stored. Optical alignment and adjustment procedure are covered in Sec. 5.0 Operating Instructions.

The lens and the target screen may require occasional cleaning if the unit has been used in dusty locations. Use lens paper and an appropriate lens cleaning agent; a soft damp cloth is satisfactory for the target screen, but be careful of the inside surface as it is made of plastic which is easily scratched. Use low pressure, dry, compressed gas to remove loose dust particles from the mirror.

6.2 Troubleshooting

If the unit malfunctions, refer to the diagnostic and remedy procedures outlined below. Perform all tests with 24 V DC supplied through the input connector.

Fault	Test
Green indicator (POWER ON) light does not come on.	Check indicator lamp. Check 2-A fuse. Check 24-V supply. Circuit board pin 1 to negative terminal, pin 7 Check 12-V supply. Circuit board pin 3 to negative terminal, pin 7. Check MR506 diode. Check M7544 regulator.
Grid pattern photographed; no laser spots.	Check operation of laser; verify that beam hits target screen. Increase exposure time and decrease lamp illumination.
Laser spots photographed; no grid pattern.	Rotate illuminating lamp control clockwise until grid appears. Remove target screen; check that all lamps are lit and replace with No. 382 bulbs as necessary. Check illumination control and 15 Ω ballast resistor, R1.

Uneven illumination of grid pattern.	Remove target screen, check that all lamps are lit; replace defective lamps with No. 382 bulbs.
Grid pattern too dim	Increase illumination by rotating control clockwise.
Grid pattern too bright.	Decrease illumination by rotating control counterclockwise.
Laser spots too dim.	Increase exposure time and/or lens aperture.
Laser spots too bright.	Decrease exposure time and/or lens aperture.
Picture completely dark.	Check shutter operation. Set T, B switch to T. Red light should come on; if not press it to test, replace if necessary. Remove film pack. Verify that the shutter is open; if not check the MJ3040 transistor and shutter coil continuity. Turn T, B switch to OFF. Check that shutter opens when green lamp is pressed; if not, check 555 timer circuit. Check that shutter opens when laser is triggered; if not, check connecting cable. Check that modifications to laser weapon fire simulator have been made (Sec. 3).

7.0 CONCLUSIONS

When used with laser or light-beam weapon fire simulators, the Mark Recorder described in this document will eliminate the use of live ammunition for arms training activities requiring quantitative measurement of the aiming point, distribution of hits, miss distances, zeroing errors, etc. This system will reduce munition costs and the need for safety personnel while extending the barrel lifetime of weapons.

The device is useable under a wide range of ambient-lighting conditions without readjustment and functions with the present Class IIIb laser weapon fire simulators used in the Tank Miniature Range. Its dynamic range is sufficient to permit operation with lower power class II lasers. It is easy to operate and requires very little time to set up since it is prefocused and exposure adjustments can be determined from a look-up table or by simple experiment according to the specific use, e.g. the number of shots required per photograph.

The Mark Recorder records an image which need not be identical to the target seen by the gunner. For example, the record could be covered with a detailed grid to aid in scoring the target hits while the target itself would remain free of unnecessary and confusing lines. The cross hair targets could also be positioned with respect to the graticule grid to compensate for the parallax effect inherent in the present laser weapon fire simulator set-up.

The device does not require special films or light-sensitive papers. Only conventional photographic materials such as Polaroid^{R} films, which are inexpensive and readily available, are used. The operating cost is, therefore, very low.

The device was tested at CFB Valcartier and CFB Gagetown and was found to fulfill all the basic requirements. It can now serve as a basis for industrial development of engineering models for use in the Tank Miniature Ranges.

8.0 ACKNOWLEDGEMENTS

The authors thank Mr. C. Denis for mechanical-design assistance with the development model and Mr. M. Bédard for measuring the Rubylith^{R} transmission curve. They also thank Mr. P.J. Price from DLAEEM, Capt M.V. Caines, Lt Smith, Adj Childs, Adj Lemieux and Sgt Houle of CFB Valcartier and Maj K.R. Seeley of CFB Gagetown for their assistance in the Tank Miniature Ranges and for their constructive comments.

9.0 REFERENCES

1. CAS (Borden), June 1970. Private Communication.

2. Tardif, L. "Helium-Neon Laser Weapon Fire Simulator", DREV TN-2076/73, November 1973. UNCLASSIFIED.

3. "Practice with handguns is simulated with an $18,000 laser target range", Laser Focus, p. 26, November 1975.

4. DLAEEM, Private Communication.

APPENDIX A

LIST OF DREV DRAWINGS

Drawing Number*	TITLE
A/77032301/H	PRACTICE TARGET MARK RECORDER
SA/77032302-D	LENSBOARD ASS'Y
" 03-C	SUPPORT
" 04-B	BACK-PLATE
" 05-C	FLANGE
" 06-B	SPACER
" 07-A	PAD
SA/77032308-D	MIRROR MOUNT ASS'Y
" 09-C	SADDLE
" 10-D	FRAME (MIRROR)
" 11-A	MIRROR
" 12-B	COVER
" 13-B	RETAINING PLATE
" 14-B	GUIDE PLATE
SA/77032315-D	TARGET ASS'Y
" 16-D	CASE
" 17-B	RAIL
" 18-C	SHIELD
" 19-C	SEAT
" 20-C	RETICULE
" 21-C	RETAINING PLATE
" 22-C	TEMPLATE
SA/76112604-C	GRATICULE
SA/77032323-H	CASE ASS'Y (MARK RECORDER)
" 24-D	ADAPTOR, CAMERA BACK
" 25-C	END PLATE
" 26-D	FRONT PLATE
" 27-D	REAR PLATE
" 28-D	BOTTOM PLATE
CA/77032329-D	COVER
" 30-B	HANDLE, CARRYING
" 31-A	SCREW, SHOULDER
" 32-D	CONTROL PANEL ASS'Y
" 33-C	SCREEN, ALIGNMENT
" 34-C	COVER, (CONTROL PANEL)
" 35-A	SPACER
" 36-A	BLADE, SPRING
" 37-B	RESSORT, SPRING
" 38-A	POST (TARGET ASS'Y)
" 39-A	GUARD (CAMERA BACK)
" 40-C	PANEL CONTROL
77052403-C	SHUTTER CONTROL CIRCUIT

*Note: Use latest amendment.

APPENDIX B

LIST OF COMPONENTS

Item	Description	Manufacturer/Supplier	Approx. Cost
Optical			
lens	105 mm f/4.5 TELESAR anastigmatic enlarging lens Cat. #50289	Edmund Scientific	$32.00
shutter	Model 225L0A3X5 Uniblitz shutter, 25-mm aperture, 5-V coil with heat sink	Vincent Associates	$57.75
film back	Model 405 Pack film holder for Type 107 film	Polaroid Corp.	$56.00
Circuit Board			
R3	Resistor 1 kΩ ½ W	Omite	0.07
R4	Resistor 1 MΩ ½ W	Omite	0.07
R5	Resistor 15 Ω 5.5 W	Sage	0.90
R6	Resistor 2.2 kΩ ½ W	Omite	0.07
R7	Resistor 1 kΩ ½ W	Omite	0.07
R9	Resistor 18 kΩ ½ W	Omite	0.07
R10	Resistor 3.3 kΩ ½ W	Omite	0.07
C1	Capacitor 500 µfd/25 V DC Electrolytic	Sprague	1.15
C2	Capacitor 0.01 µfd/600 V DC Mylar	CDE	0.35
C3	Capacitor 1 µfd/50 V DC tantalum	Mallory	0.60
C4, C5	Capacitor 0.001 µfd/600 V DC Mylar	CDE	0.35 ea
D1	Silicon diode MR506, 2.5 A, 600 PIV	Motorola	0.70
D2-D4	Silicon diode 1N4007, 1 A, 1000 PIV	Motorola	0.55 ea
Q1	Transistor MS4034 NPN, Silicon Power Darlington	Motorola	5.90
IC1	Voltage regulator M7812CP, 12 V, 1 A	National Semiconductor	3.05
IC2	Timer 555	Signetics	2.95
J1	Micro jack TR-2A	Switchcraft	0.50
Control Panel			
R1	Resistor 15 Ω 25 W wirewound	Sage	1.25
R2	Potentiometer 25 Ω wirewound 12½ W	Omite	1.30
R8	Potentiometer 100 kΩ	Allen-Bradley	3.30
S1	Switch SPDT 4 A @ 28 V MST 115 D	Alcoswitch	2.16
S2	Switch SPDT, center OFF, momentary contact on one side. MST 105 H	Alcoswitch	2.46

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